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SEASONAL VARIATION IN BIRDSTRIKE RATE FOR TWO NORTH AMERICAN RAPTORS: TURKEY VULTURE (*CATHARTES AURA*) AND RED-TAILED HAWK (*BUTEO JAMAICENSIS*)

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Herein I present an analysis of Bird Avoidance Model (BAM) methodology using records from birdstrikes of U.S. Air Force (USAF) aircraft with two North American raptor species: Turkey Vultures (*Cathartes aura*) and Red-tailed Hawks (*Buteo jamaicensis*). The relationship between six seasonal behavioral activities and the rate of collisions was used to determine whether, as BAM methodology assumes, migration is the behavior that causes the highest risk of collisions. I found that vultures are more likely to be in collisions with aircraft in the summer season, when the young of the year have left the nest, but before autumn migration begins. Conversely, Red-tailed Hawks are more likely to be in collisions with aircraft when adults have eggs in the nest. The lowest risk of a collision between an aircraft and either species is during the winter months.

TEMPORAL VARIATION IN BIRDSTRIKE RATE

Turkey Vultures (31%) and Red-tailed Hawks (32%) account for the majority of damaging raptor strikes to USAF aircraft. In 1985, the USAF Bird Aircraft Strike Hazard (BASH) team developed a raptor avoidance model to compliment the waterfowl model developed in 1982 (Merritt 1990). The raptor model was constructed using data supplied by the Hawk Migration Association of North America (HMANA). The 1985 USAF Raptor Avoidance Model (BAM) recognizes only two activities, migration and foraging flights, and it makes two key assumptions about the conflict between birds and aircraft: (1) that the standing populations of raptors in winter and summer present a constant risk of birdstrikes; (2) that migration increases the number and risk of birdstrikes. The formula for the BAM includes a constant to decrease the number of raptors potentially encountered during wintering and breeding seasons, in keeping with the significantly greater risk posed to aircraft by migrants compared to sedentary breeders or winterers (Mindell 1985).

To test these assumptions, I constructed annual activity tables for both Turkey Vultures and Red-tailed Hawks by subdividing the U.S. into the three areas of longitude used in the BAM: East (55–87°), Central (87–104°) and West (104–130°). Within each of these six tables, data were grouped on the *y*-axis at intervals of 2° latitude to show clinal variation in seasonal activities.

Six categories of seasonal activities were described by the activity tables. They included wintering, spring migration, eggs in nest, young in nest and summer and autumn migration behavior categories. The peak autumn and spring migration periods were obtained from count data for each species from HMANA data. Time periods for eggs in nest and young in nest were obtained directly from North American Nest Record Scheme data provided by the Cornell Laboratory of Ornithology for Red-tailed Hawks and from Jackson (1983) for Turkey Vultures. A regression line was passed through the mean dates for eggs in the nest at each 2° line of latitude. Lines with similar slopes were used to indicate start and finish dates for eggs in nest and young in nest periods. The time between the end of autumn migration and the start of egg laying or spring migration was designated as the wintering period. Likewise, the period between the end of young in nest and the start of autumn migration was determined to be the summer period. The spring migration and eggs in the nest seasons overlapped wholly or partly at some latitudes. The overflight of southern breeders by migrants heading north has been recognized for Red-tailed Hawks (Palmer 1988).

Using the BASH database, birdstrikes at known geographic locations were plotted as a circle onto the appropriate activity table. All strikes away from airfields and those near airfields but above 70 m were also included. The raptor BAM can be used to calculate the risk of a strike when approaching or departing an airfield, as well as on low-level routes, so data fitting this latter profile were also

Table 1. Seasonal variation in Turkey Vulture strikes in all regions of the U.S.

Season	Observed Number of Strikes	Expected Number of Strikes	% Diff.
Winter	59	106	−44%
Spring migration	26	32	−19%
Eggs in nest	27	31	−10%
Young in nest	96	78	+23%
Summer	54	29	+86%
Autumn migration	44	34	+29%

$\chi^2 = 50.9017$, $P < .001$.

Table 2. Seasonal variation in Red-tailed Hawk strikes in all regions of the U.S.

Season	Observed Number of Strikes	Expected Number of Strikes	% Diff.
Winter	36	58	−37%
Spring migration	27	19	+42%
Eggs in nest	41	28	+46%
Young in nest	42	43	−2%
Summer	38	35	+9%
Autumn migration	28	34	−18%

$\chi^2 = 19.0882$, $P < .01$.

included. The data covered the period from 1975–92. Based on my analysis, I concluded that the raptor BAM had a minimal effect on the strike rate for these two species since 1985. The temporal and spatial distribution of strikes from 1985–92 was consistent with that of 1975–85. The effectiveness of the raptor BAM is severely diminished by the dominance of Broad-winged Hawks *(Buteo platypterus)* in HMANA data. The Broad-winged Hawk is rarely struck by aircraft. Conversely, the Red-tailed Hawk and Turkey Vulture, which are frequently struck, are underrepresented in HMANA data.

Counts were made of the number of strikes during each season and then compared with the expected number of strikes during that period with Chi-square Goodness-of-Fit Test. To avoid totals in any season less than five, which would invalidate the test, counts from all three regions were summed before analysis (Tables 1, 2, Figs. 1, 2).

The data indicated that the collision risk for aircraft varies according to season for Turkey Vultures ($\chi^2 = 50.9017$, $P < 0.001$) and for Red-tailed Hawks ($\chi^2 = 19.0882$, $P < 0.01$). The variation in strike rate in each season did not support the assumption that migratory activity was responsible for increasing the number of birds aloft and hence, the hazard posed to aircraft. During the autumn migration, Red-tailed Hawks had a strike rate below average, although Turkey Vultures showed a 29% ($N = 10$) increase in their strike rate. During spring migration, the strike rate for Turkey Vultures fell 19% ($N = -6$) but the strike rate for Red-tailed Hawks rose 42% ($N = 8$). Therefore, the BAM did not reflect accurately the strike rate for either species during one of their two migratory seasons.

Both Turkey Vultures and Red-tailed Hawks showed a marked decline in the number of bird-strikes during the wintering period (−44%, $N = -47$ and −37%, $N = -22$, respectively). This was due to the relationship between thermal activity and strike rate for these two species. Both forage

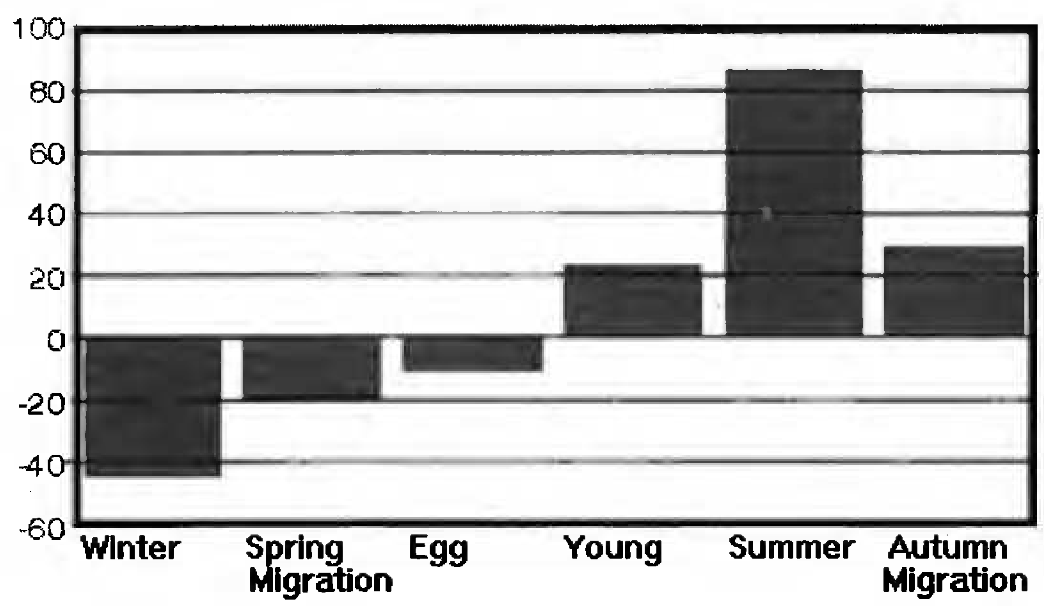

Figure 1. Percent seasonal variation in mean strike rate of Turkey Vultures.

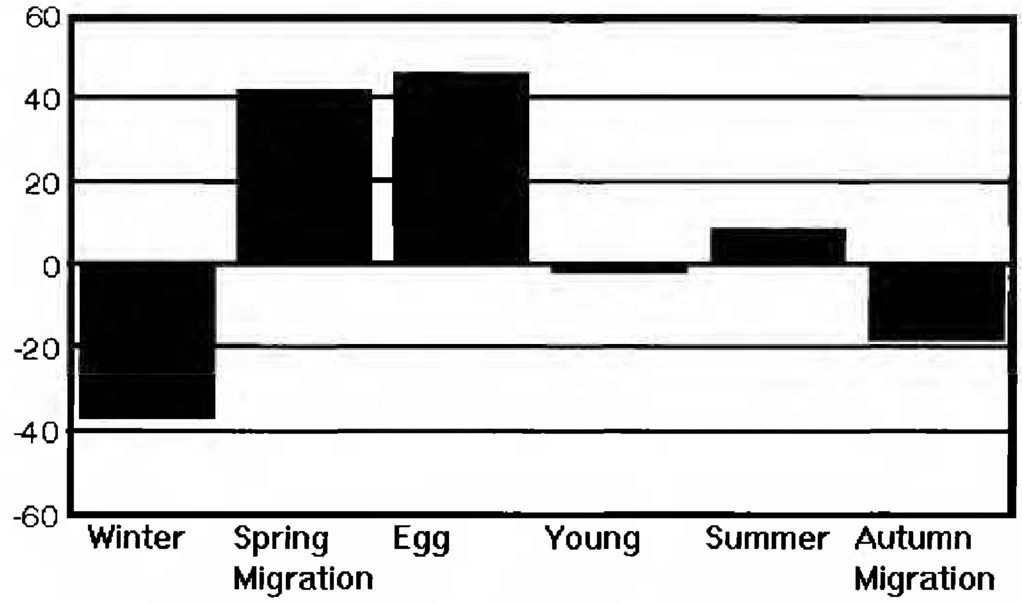

Figure 2. Percent seasonal variation in mean strike rate of Red-tailed Hawks.

by soaring on thermals, without which they are unlikely to reach the height required to bring them into conflict with aircraft. The shorter day for raptors to forage in winter, higher natural mortality, increase in aircraft night flying, flights lost due to poor weather and the holiday period could all be contributing factors in reducing the strike rate during this period. During winter, migration lowers the density of both species in many northern areas of North America and there is a low likelihood of thermal conditions capable of bringing aircraft and soaring birds into conflict. This means that only a small number of flight routes are unsuitable.

In the summer period, there was a marked difference in strike rate between Turkey Vultures (86% above the mean, $N = 25$) and Red-tailed Hawks (9% above the mean, $N = 3$). This was the period with the highest risk of Turkey Vulture strikes. The breakup of nesting territories of Red-tailed Hawks and the decline in soaring for territorial defense would reduce the amount of time spent on thermals. Furthermore, Red-tailed Hawks, which take live prey rather than carrion, are likely to spend progressively less time foraging as prey become more abundant and the juvenile dependency period ends. Turkey Vultures of any age need to gain altitude and spend time on thermals to locate their carrion food by visual and olfactory means. Mortality of the species that form their carrion diet is also relatively low in the period before winter arrives. The time spent foraging each day would, therefore, be high during this period. The strike rate with Turkey Vultures possibly matches the increase in population density and foraging time.

During the period when eggs are in the nest, Turkey Vultures showed a below average strike rate (-10%, $N = -3$). At the same time, Red-tailed Hawks reached their peak strike rate (46% above the mean, $N = 13$). Red-tailed Hawks soar to advertise their presence in the territory. During the incubation period, males must secure mates, forage and maintain territories that enclose adequate food supplies for breeding. The high strike rate for Red-tailed Hawks was likely a consequence of the intensity and altitude of soaring flight.

Turkey Vultures had a strike rate 23% above the mean ($N = 18$) when young were in the nest and Red-tailed Hawks were very close to the mean strike rate (-2%, $N = -1$). This suggested that more Turkey Vultures spend more time soaring in aircraft airspace when young were in the nest. Red-tailed Hawks, conversely, spent less time in the altitude band in conflict with aircraft when young were in the nest than during the incubation period.

The seasonal variation in strike rates showed that the first assumption of the current raptor BAM is flawed. The standing populations in winter and summer do not pose a constant risk to aircraft of birdstrikes. The results show that migration is not an important factor in bringing the two species into conflict with military aircraft. A change in military flying tactics could result in aircraft routinely flying in the altitude band used by migrants. Further research is required to isolate which aspects of Turkey Vulture and Red-tailed Hawk ecology and behavior have the potential to bring them into conflict with aircraft. The equations used to calculate risk of a birdstrike with the study species should not seek to minimize the effect of the standing population. This will permit the BAM to be effective in identifying risk even when military tactics change.

The birdstrike databases kept by many nations represent a valuable resource for identifying possible ecological factors affecting the strike rate with aircraft. To be analyzed effectively, they need to be compared with other ornithological databases. The results of such tests can be used to formulate hypotheses and establish research priorities. This is a low cost first step to solving raptor/aircraft conflicts and establishing an improved bird avoidance model.

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